Ministry of Education

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OAC Teacher In-Service Program

Criteria for the Design of the Examination and the Evaluation of Student Responses in OAC PHYSICS

Draft Handbook

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Table of Contents

Introduction 1

Background 1

Purpose of the OAC Physics Handbook 1

Needs Assessment 2

Design of the OAC Physics Examination 3

Examination Format 4

Preparing Students for the Examination 8

Apportioning the Marks 8

Practical Laboratory Examination 9

Sample Examination for the OAC in Physics 10

Conclusion 10

APPENDIX A 11

APPENDIX B 45

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Handbook for Evaluating the OAC in Physics

1. Introduction

The curriculum guideline, Science Intermediate and Senior Divisions 1987 - Part 1 Program Outline and Policy requires that:

Each student who wishes to complete successfully a science OAC shall write at least one formal examination in that OAC. A student may not be exempted except in the case of emergency or illness. The examination for each science OAC shall be allotted at least 30 per cent, but not more than 40 per cent of the final mark. If only one examination is used towards the evaluation of student achievement for an OAC, it should be based on more than one-half of the course (preferably on most of the course). (Part 1, page 69)

2. Background

The end of provincial exams has led to concerns by the public and post secondary institutions about mark variability and mark inflation. Province wide consistency is difficult to ensure when each school sets its own examination and marking scheme.

The Ontario Assessment Instrument Pool for physics published in 1981 provided a bank of test questions and supporting resource material to assist teachers with the setting and marking of examinations.

The first step in providing greater consistency in marking examinations began in 1986 with the production of A Handbook For Designing and Marking the OAC 1 English Written Examination which prescribed a common examination for OAC 1 English and detailed its design and marking. Subsequent workshops were given to assist teachers with the implementation of the common format examination. Two years later in 1988 all secondary schools submitted to the Ministry a final examination and three student responses - superior, average, and low achievement for OAC 1 English. A provincially appointed team analysed the design and marking of the examination, and produced an individual report for each school indicating whether or not the design and marking of the examination met the expectations of the Ministry. A provincial report was also produced that summarized the provincial results.

3. Purpose of the OAC Physics Handbook

This handbook carries the process forward to OAC Physics. Its aim is to prescribe a common format for the OAC Physics examination and outline its design and marking. Workshops for teachers of OAC Physics will be offered to provide more information. An implementation and review process similar to the

one for the OAC 1 English examination will follow. The institution of a common examination format is expected to result in more consistent student marks in OAC Physics.

4. Needs Assessment

A needs assessment related to the physics OAC conducted in the spring of 1989 of a sample of English and French language secondary schools across the province revealed the following:

(a) Examination Format

- the number of examinations varied from one to three;
- the length of examinations varied from one to three hours;
- about one half of the schools reported that they do not use the items included in the OAIP Physics pool;
- most examination questions were chosen from textbooks or past examinations;
- most schools based the examination on the whole course;
- most schools included a question on the examination related to laboratory work;
- about 30% of schools included questions on the examination related to the applications or societal implications of physics;
- marks were generally not assigned for appropriate language usage;
- about 75% of schools included multiple choice questions on the examination.

(b) Cognitive Levels of Questions

- most schools reported a balance of question types including recall, problem solving, and application.

(c) Examination Aids

- all schools indicated that students were allowed to use calculators. About one half of the schools did not allow programmable calculators;
- about one half of the schools reported that students were allowed to use memory aids such as an information sheet.

(d) Contribution of the Examination Mark to the Student's Final Grade

- schools reported a range of 18% to 60%;

- in most schools students were not exempted from the final examination.

(e) Issues to be Addressed

- number of examinations;
- length of examinations;
- source of examination questions;
- examination content;
- question formats;
- cognitive level of questions;
- utilization of examination aids;
- contribution of the examination mark to the final grade.

5. Design of the OAC Physics Examination

The components of formal examinations for the OAC Physics are outlined in Science, Intermediate and Senior Divisions, 1988, Part 14, Physics.

Examinations. The formal examination(s) required of all students and worth from 30 to 40 per cent should contain a variety of types of questions such as alternate response, multiple choice, and matching selected-response types; short answer, completion, restricted and extended-essay types; numerical types; and where feasible types that involve laboratory skills. The formal examination may consist of written and laboratory components. These components may occur close together or weeks or months apart. (Part 14, page 9)

In designing the OAC Physics examination teachers should consider the following criteria:

- the examination should include a variety of question formats at various levels of difficulty;
- students should have had experience in the course with the particular question types included on the examination;
- questions on the examination must be based on the objectives included in the Ministry guideline for OAC Physics;
- the amount of time required to do a question on the examination should be reflected in the marks allocated to the question;
- questions on the examination should reflect real life situations, e.g., a question on forces should deal with forces that might realistically exist in the given situation;
- the marks allocated to each question should be printed beside the question on the examination paper;

- the examination should begin with easier questions;
- questions of the same type, e.g. multiple choice, should be grouped together;
- metric editorial style as outlined in Part 1 (page 38, Appendix B) of the Science Guideline must be followed in all questions;
- the examination questions should reflect the correct use of significant digits as outlined in Part 1 of the Science Guideline on page 40.

In preparing the examination attention should be paid to the following points:

- questions should occur on the examination for all the core units and those optional units which are taught;
- the marks allocated to the questions on the examination should reflect the time allocations in the Ministry guideline;
- the examination should include questions dealing with laboratory work, mathematical problem solving, and the applications and societal implications of physics;
- the examination should contain one extended response question which could deal with a societal issue;
- short answer questions that test a student's understanding of basic physics principles should be included;
- the examination should include a range of questions that test knowledge, applications, and higher order thinking skills.

Note: Traditional mathematical problem solving questions in Physics could be at the application or higher order thinking skill level depending on the nature of the question. Questions where students follow a "type" studied in class are probably best considered as application questions. Questions involving higher order thinking skills generally require the student to solve problems presented in a different context to the examples used in the classroom. Questions of this type generally require students to use the skills of analysis, synthesis and evaluation.

6. Examination Format

(a) Number of Examinations

All OAC Physics students must write at least one formal examination which is worth between 30 and 40% of the final mark. It is strongly recommended that this be a final examination at the end of the course and that all students should write this examination.

(b) **Duration of the Examination**

The OAC Physics examination should be from 2 to 2.5 h in duration.

(c) **Examination Cover Page**

Each examination must include a cover page which contains general information such as student name, breakdown of mark allocation by section of the examination, suggested time to complete each section of the examination, and the necessary physical constants to answer the questions.

(d) **Content of the Examination**

Questions on each of the core units must occur on the examination. Questions should also occur on the examination for any optional units studied in the course. The proportion of marks allocated to questions should approximate the time allocations in the guideline.

Core Unit	Suggested Time Allocation
Kinematics	20%
Dynamics	20%
Momentum and Energy	20%
Electrostatics	10%
Waves and Light	20%
Early Quantum Theory	10%

Note: If optional units are included on the examination the suggested time allocations should be adjusted accordingly.

(e) **Question Types**

Examinations in OAC Physics should include questions of the following types:

Question Type	Suggested Mark Allocation
Multiple Choice	15-25%
Laboratory	10-15%
Extended Response	10-15%
Problem Solving	45-65%

Note: Problem solving questions could include short answer questions as well as traditional mathematical types. Examples of each type are included in the sample examination in Appendix A.

(f) Multiple Choice Questions

This type of question provides an efficient way of covering a wide range of material from the Ministry guideline. This is often a question type that students encounter in their university work. These questions should generally be one step questions used to test single concepts or principles in physics where it is appropriate to award one mark for the correct choice. Teachers may wish to award 2 marks per question for a selection of more difficult questions. In this case fewer questions would be asked and students would spend more time per individual question. Generally, questions of this type are better presented in a short answer format where part marks may be awarded for a partial answer. In any case, each multiple choice question should have the same mark value. Questions that require extensive work by the student are not appropriate as multiple choice questions. The OAIP for physics is an excellent source of multiple choice questions and should be consulted often by teachers.

(g) Laboratory Questions

Every examination should include at least one question that deals with some aspect of laboratory work. These questions should focus on the appropriate skill objectives and the student activities outlined in the guideline. Questions of this type could be designed for any of the core units. Questions that deal with the interpretation and analysis of laboratory data, or the design of a experiment to investigate a problem are types that would be suitable. If a practical examination is held separately from the written examination the 10-15% of the marks allocated for the laboratory portion of the written examination could come from the practical examination. The remaining sections of the written examination would be adjusted appropriately.

(h) Extended Response Questions

One question should be included on the examination which requires students to write an extended response. This type of question could focus on a particular area of physics where students are asked about the appropriate applications and societal implications of the physics concepts and principles involved. Depending on the nature of the question, a laboratory question could also be answered in an extended response format. These questions

provide an excellent opportunity in which to address the science, technology and society interface. Students must be given many opportunities to attempt questions of this type in the regular classroom program prior to the examination.

(i) Problem Solving

These questions can be of the short answer type or of the traditional mathematical type. Short answer questions can deal with the students' understanding of a particular physics concept or principle. Mathematical questions more often involve many steps and the application of several physics equations. Part 14 of the guideline describes mathematical work as follows:

> **Mathematical Work.** The OAC in physics is more rigorous than the grade 12 course and treats many topics in greater depth. It is intended to prepare students for further studies in physics at the university level and therefore places more emphasis on problem solving than its prerequisite course. In order to help students realize that the various areas of physics can be interrelated mathematically and are often interdependent, opportunities should be provided, particularly towards the end of the course, for students to solve problems involving concepts from two or more areas, such as mechanics, electricity, wave phenomena, and modern physics (Part 14, page 9).

(j) Examination Aids

The cover page of the examination must include those physical constants required by students to answer the examination questions. In addition students should be able to use on the examination the calculator of their choice. Teachers may require students to clear the memory of programmable calculators. Students are required to prepare prior to the examination an information sheet that includes appropriate equations and other pertinent information that would be useful to them during the examination. After approval by the physics teacher this information sheet may be used on the examination. More learning will take place in the preparation of the page than would be the case if a teacher-prepared page is used. The preparation of this sheet by students represents a valuable review and organizational task. The nature of the questions asked on the examination should reflect the use of these aids.

7. Preparing Students for the Examination

To assist students with their preparation for the examination, regular classroom time must be provided for students to practise the skills necessary to answer the examination questions. For example similar types of questions should be used on classroom tests. Question types should not appear on the examination that have not been presented in the classroom during the regular program.

Students must be taught how to approach different types of examination questions. For example in questions with several mathematical steps, students should be encouraged to carry calculations through to completion even though they may have made an error in an early step. Students should be told to assume an answer to a part of the question that they were unable to complete so that the remainder of the question can be completed and the appropriate number of marks awarded.

In science courses, particularly in the Senior grades, it is recommended that solutions to problems indicate the units throughout the entire solution to each problem. If the solution to a problem becomes too complex because of the inclusion of units within the solution, such units should be shown to the right of the appropriate line of numerical values. (Part 1, page 42.) It should be emphasized that this is a process that can help students to determine the correct solution. Students should be encouraged to carry the units in solutions to problems on the examination when it would help them to determine the correct solution. Students should understand that carrying units may make it easier for the teacher to assign part marks in a solution when an error has been made. In any case students must state the final answer with correct units.

Practice must also be provided in answering extended response questions. The importance of a concise and logical argument based on an understanding of the appropriate principles of physics should be emphasized.

Consideration should also be given to distributing the cover sheet of the examination prior to the examination. This provides students with an opportunity to plan their approach to the examination. Students should be advised to follow the time allocations closely. When the amount of time allocated to a question expires students should be encouraged to go on to the next question.

8. Apportioning the Marks

The sample examination in Appendix A of this handbook includes a marking scheme. The marking schemes for the various questions should be considered

carefully as a model to provide consistency in marking.

In general, the amount of time needed to complete a question should determine the number of marks allocated to that question. Marks should be given for an understanding of the principles and concepts of physics. An undue emphasis on arithmetic and algebraic manipulations should be avoided.

Marks should be allocated in the questions involving mathematical solutions for each clearly identifiable step or element which makes an essential contribution to a correct or complete answer. For example, marks should be given for the problem set up, use of appropriate equations, the mathematical computations and the final answer. The ticks used in the sample solutions included with the examination indicate scoring points or steps in the solution. Each tick has a fractional value and does not correspond to a full mark. A detailed discussion of the allocation of marks in this type of question is found in Appendix B (Part III of the Physics OAIP on pages 4 to 6).

The extended response question should be marked based on the student's knowledge of the appropriate physics, and ability to develop a logical and concise series of statements. A small number of marks (2% or 3%) may be deducted over the entire examination for incorrect grammar and spelling. This should be common practice throughout the course.

A small proportion of the marks (2% or 3%) should be allocated to the correct use of significant digits and metric editorial style throughout the entire answer paper.

9. Practical Laboratory Examination

The use of a practical component is an excellent addition to the formal examination. Although it is not required, teachers are encouraged to include this component in their evaluation of student work. It could be used in lieu of the laboratory question on the written examination.

This practical laboratory examination could be held in the classes immediately prior to the end of the term. Such an examination should focus on the students' ability to make measurements and observations, interpret laboratory findings and design simple experiments. It should be based on the activities and skills which are outlined in the guideline. Examples could include the determination of a spring constant, measurement of the coefficient of friction, and the determination of the acceleration due to gravity by different techniques.

The time allotted to the practical examination should be in addition to the formal written examination. The marks allocated to the practical examination should be considered as part of the 30 to 40% of the student's final mark which is derived from examinations.

Practical examinations are not now a common component of the evaluation of students in OAC Physics. As teachers acquire experience in this area the practical examination should become a regular part of the student's end of term evaluation.

10. Sample Examination for the OAC in Physics

Included in Appendix A of this handbook is a sample examination and accompanying marking scheme for the OAC in physics developed using the criteria outlined in this handbook. As is the case with all examinations, this examination can be improved. Teachers are encouraged to study the criteria, the examination and the marking scheme and to recommend areas where improvements can be made.

11. Conclusion

Teachers of physics are expected to follow the criteria outlined in this handbook when final examinations are prepared. Copies of the examinations and the marking schemes are to be retained.

In the future the Ministry will collect a sample of examinations, marking schemes and student papers from each school in the province. A report will be prepared for Directors of Education indicating the appropriateness of examinations in their jurisdiction.

APPENDIX A

Sir Isaac Newton High School
Final Examination
Physics OAC

Name: _____ Time: 2.5 h
Date: June 1990 Time: 9:00 am. No. of Pages _____

NOTE:
1. You may use an information page which has been authorized by the teacher. This is to be submitted with your examination answers.

2. You may use a calculator, ruler, protractor, compass and mathematical tables.

3. Assume all data is accurate to the number of digits given and round off your answers appropriately.

4. Your solutions to the mathematical problems should contain enough detail that part marks may be allocated for incorrect solutions.

5. The examination consists of the following parts. The marks for each part and the time you should take to answer the questions is shown below:

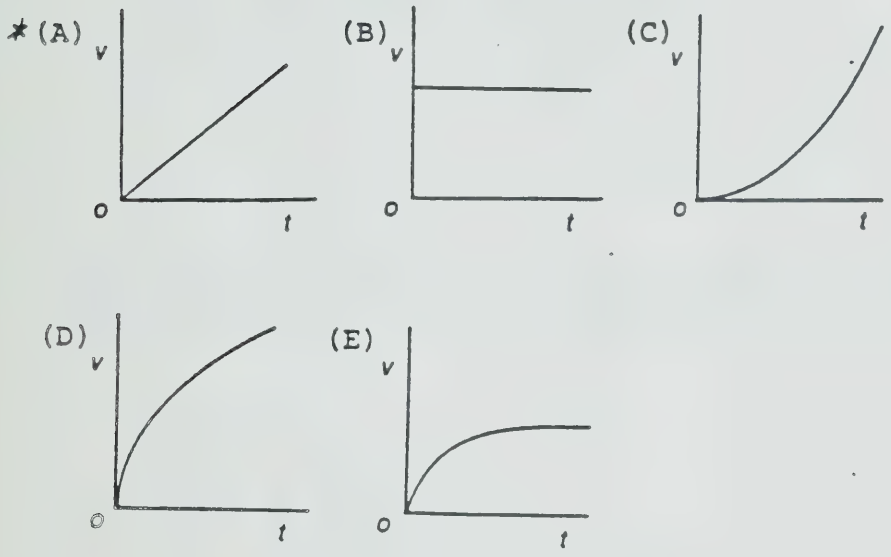
Part A - Multiple Choice	25 marks	35 min
Part B - Short Answer	9 marks	15 min
Part C - Problems	44 marks	60 min
Part D - Laboratory Problem	13 marks	20 min
Part E - Extended Response	12 marks	20 min
Significant digits and metric usage	2 marks	
Grammar and spelling	2 marks	
TOTAL	107 marks	150 min

The following values may be used:

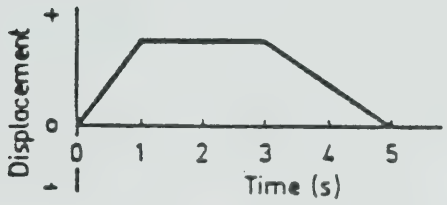
acceleration due to gravity	$g = 9.80\ m/s^2$
gravitational field constant	$g = 9.80\ \frac{N}{kg}$
universal gravitational constant	$G = 6.67 \times 10^{-11}\ \frac{N \cdot m^2}{kg^2}$
speed of light in air	$c = 3.00 \times 10^8\ m/s$
Coulomb constant	$k = 8.99 \times 10^9\ \frac{N \cdot m^2}{C^2}$
	$k = 2.31 \times 10^{-28}\ \frac{N \cdot m^2}{elem.chg^2}$
1 elementary charge	$e = 1.60 \times 10^{-19}\ C$
1 electron volt	$eV = 1.60 \times 10^{-19}\ J$
Plank's constant	$h = 6.63 \times 10^{-34}\ J \cdot s$
mass of an electron	$m_e = 9.11 \times 10^{-31}\ kg$
mass of a proton	$m_p = 1.67 \times 10^{-27}\ kg$
mass of a neutron	$m_n = 1.67 \times 10^{-27}\ kg$

Part A - Multiple choice - 25 marks (35 min)

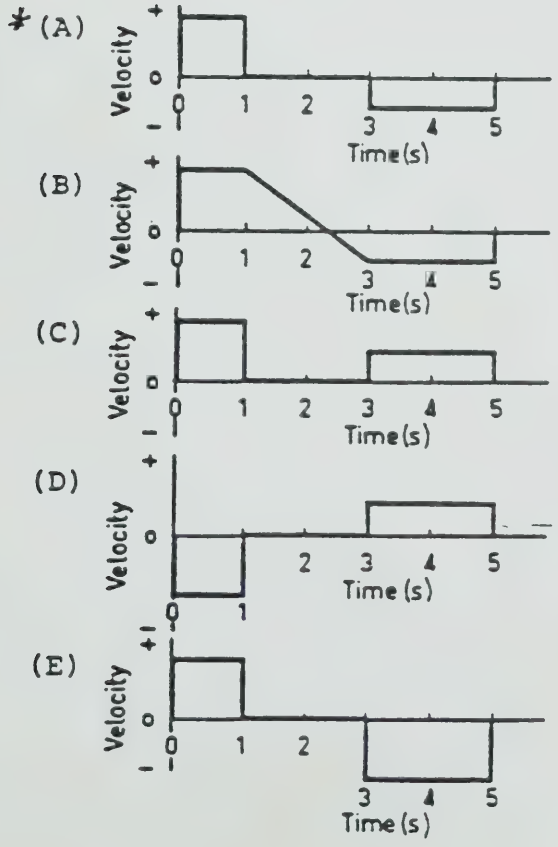
1. If air resistance is neglected, which graph best represents a speed-time graph for an object dropped from a building?



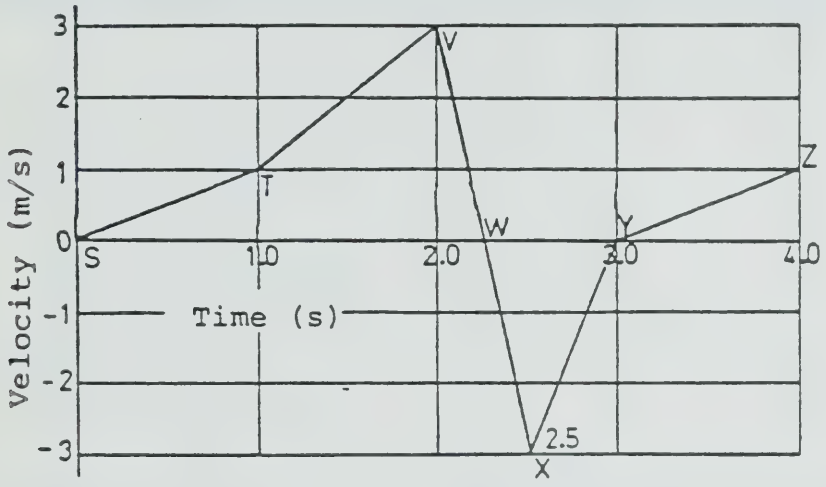
2. The following graph represents a displacement-time graph for an object during a 5 s time interval.



Which one of the following graphs of velocity versus time would best represent the velocity of the object during the same time interval?



3. A particle moves in a straight line as described in the graph below.



At what point during the four seconds is the particle's displacement from its starting position S the greatest?

(A) V

*(B) W

(C) X

(D) Z

(E) none of the above

4. An airplane is flying at a constant speed of 500 km/h. It executes a slow turn that changes its direction of travel from north through east to south. If the turn takes 40.0 s, the airplane's average acceleration is

(A) 12.5 (km/h)/s [N]

(B) 12.5 (km/h)/s [S]

(C) 12.5 (km/h)/s [E]

(D) 25.5 (km/h)/s [N]

*(E) 25.0 (km/h)/s [S]

5. If a particle moves at constant speed in a circular path, then the instantaneous velocity vector and the instantaneous acceleration vector are

(A) both tangent to the circular path

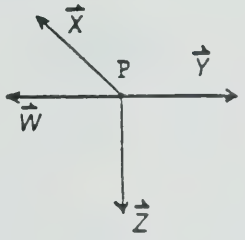
(B) both perpendicular to the circular path

*(C) perpendicular to each other

(D) opposite in direction

(E) none of the above

6. Vectors $\vec{W}$, $\vec{X}$, $\vec{Y}$ and $\vec{Z}$ represent forces of equal magnitude acting on a point P as shown.



Which of the following vectors best represents the resultant (net) force acting on P?

*(A)

(B)

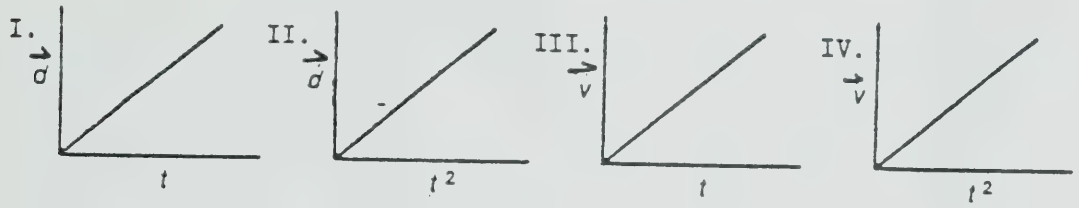
(C)

(D)

(E)

7. A constant force is used to accelerate an object from rest along a smooth horizontal surface. Which single graph, or pair of graphs, shown below correctly describes the resulting motion of the object?

($\vec{d}$ = position, t = time, $\vec{v}$ = velocity)



(A) I only

(B) II only

(C) III only

*(D) II and III only

(E) I and IV only

8. A 700 kg elevator suspended by a cable accelerates downwards at 3.0 m/s^2. The force exerted by the cable on the elevator is

(A) 2.1 kN [upwards]

(B) 2.1 kN [downwards]

*(C) 4.8 kN [upwards]

(D) 9.0 kN [downwards]

(E) 9.0 kN [upwards]

9. Two objects, of mass m_1 and m_2, are subject to the same constant net force. If the acceleration of m_1 is four (4) times that of m_2, the ratio of m_1 to m_2 (i.e., $\frac{m_1}{m_2}$) must be

(A) 8

(B) 4

(C) 2

(D) ½

*(E) ¼

10. An object moves in a circular path at constant speed. If the radius of the path is doubled but the speed remains the same, the centripetal force is

(A) twice as great

*(B) half as great

(C) four times as great

(D) one fourth as great

(E) unchanged

11. If the separation between the centres of two masses is reduced to 1/3 of its former value, the gravitational force between them is multiplied by

(A) 1/9

(B) 1/3

(C) 3

(D) 6

*(E) 9

12. A 2.0 kg frictionless puck is at rest on a level table. It is pushed straight north with a constant force for 1.50 s and then let go. The speed then is 3.0 m/s. The momentum of the puck at the end of 1.50 s is

(A) 3.0 kg·m/s

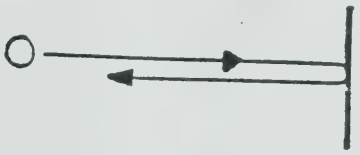
(B) 3.0 kg·m·s [N]

(C) 6.0 kg·m/s

(D) 6.0 kg·m·s [N]

*(E) 6.0 kg·m/s [N]

13. A ball of mass 2.0 kg moving with a horizontal velocity of 5.0 m/s to the right hits a vertical wall and rebounds with a horizontal velocity of 4.0 m/s to the left as shown in the diagram below.



The magnitude of the change in momentum of the ball is

(A) 2.0 kg · m/s

(B) 5.0 kg · m/s

(C) 9.0 kg · m/s

(D) 10 kg · m/s

*(E) 18 kg · m/s

14. A 75 kg man was riding on a 30 kg cart travelling at a speed of 2.0 m/s relative to the ground. He jumped off in such a way that he landed on the ground with no horizontal speed. What was the resulting change in the speed of the cart?

(A) 0

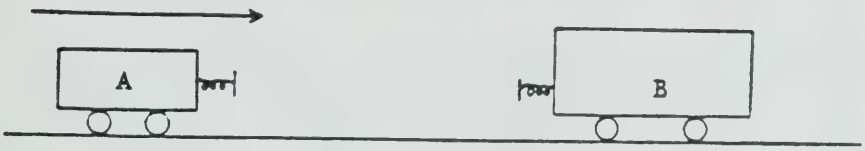
(B) 2.0 m/s

(C) 3.0 m/s

*(D) 5.0 m/s

(E) 7.0 m/s

15. Car A of mass 2 kg approaches and collides with car B which has a mass of 3 kg and is initially at rest.



When the separation between the cars is a minimum, then

(A) car B is still at rest and car A is moving

(B) car A has come to rest and car B is moving

(C) both cars have the same kinetic energy

(D) both cars have the same momentum

*(E) the kinetic energy of the system is a minimum

16. The conclusion from the Millikan oil drop experiment was that

(A) the mass to charge ratio of the electrons is very small

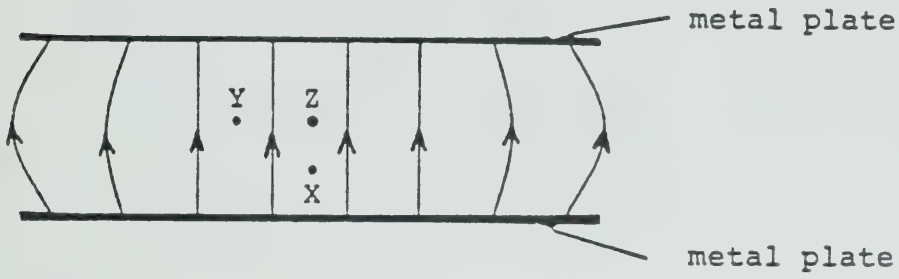
(B) the speed of the electrons is very great

(C) the electron has a negative charge

(D) the proton has a positive charge

*(E) there exists a smallest electric charge

17. The diagram below shows the electric field (fine lines) created by a pair of uniformly charged parallel metal plates (heavy lines).



Which one of the following statements can be deduced correctly from the diagram?

(A) The top plate is positive and the bottom plate is negative.

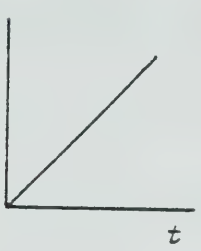
*(B) A positively charged small sphere at X would experience the same electric force as it would if it were placed at Y.

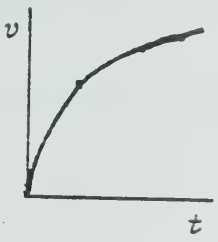
(C) A positively charged small sphere at X would experience greater electric force than if it were at Z.

(D) A positively charged small sphere at X would experience less electric force than if it were at Z.

(E) A negatively charged object located between the plates could have the gravitational force on it balanced by the electric force caused by the plates.

18. Which graph best represents the speed of a charged particle in a uniform electric field as a function of time?

*(A)


(B)


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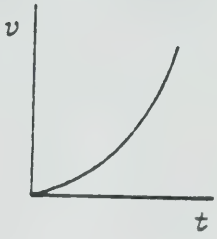

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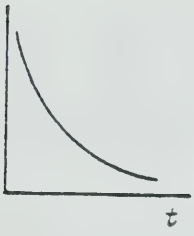
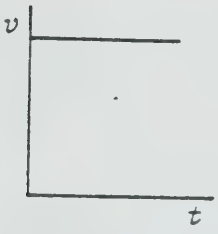


(E)


19. The diagram below shows a portion of a rope in which a disturbance XY travels in the direction of the arrow.

The instantaneous velocity of a particle of the rope at point P is best represented by which one of the following vectors?

*(A)

(B)

(C)

(D)

(E)

20. A point P is one half a wavelength farther from one source than from another identical source.

If the two sources are in phase, then at P there is

(A) constructive interference of the waves.

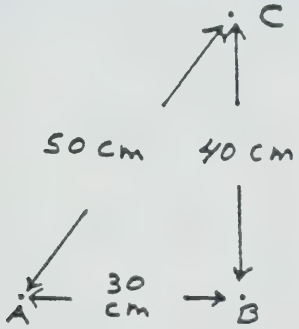
*(B) destructive interference of the waves.

(C) no interaction between the waves.

(D) both constructive and destructive interference at the same time.

(E) constructive interference followed by destructive interference at regular intervals.

21. Two small loudspeakers are located at A and B as shown in the diagram below.



The sound intensity measured using a microphone located at point C is greatest when the wavelength of the sound is

*(A) 10 cm

(B) 20 cm

(C) 30 cm

(D) 40 cm

(E) 70 cm

22. Which of the following properties of light is Young's double slit experiment designed to demonstrate?

(A) diffraction

(B) dispersion

(C) graininess

*(D) interference

(E) polarization

23. The maximum kinetic energy of the most energetic photoelectrons ejected from the surface of the metal lithium by a monochromatic beam of light is 3.8 eV. The photoelectric work function (threshold energy) of lithium is 2.5 eV. What is the energy of a photon of this light?

(A) 1.3 eV

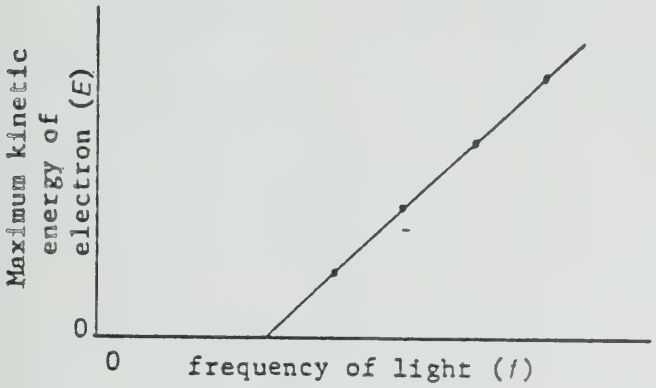
(B) 2.5 eV

(C) 3.2 eV

(D) 3.8 eV

*(E) 6.3 eV

24. The graph represents the result of an experiment in which light falls on a metal surface. The kinetic energy of the most energetic electrons emitted (E) is plotted against the frequency of the light (f).



Here are three suggested changes in the experimental conditions:

I. Use light with a wavelength shorter than any used above.

II. Use light of the same wavelength but of greater intensity.

III. Use a metal surface with a different work function (or threshold energy).

For which of the above changes would the readings fall on the original straight line of the graph or its extension?

(A) I only

*(B) I and II only

(C) I and III only

(D) II and III only

(E) I, II and III

25. A given source produces light having a wavelength of 5.0×10^{-7} m. Given that $h = 4.1 \times 10^{-15}$ eV·s, what is the energy carried away by one photon from this light source?

*(A) 2.5 eV

(B) 0.40 eV

(C) 8.2×10^{-9} eV

(D) 2.1×10^{-21} eV

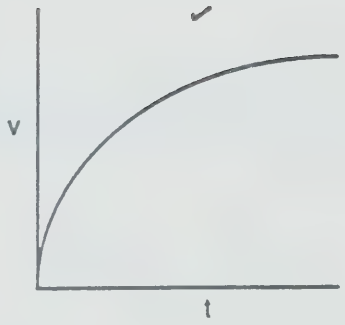
(E) 6.8×10^{-30} eV

Part B - Short Answer - 9 marks (15 min)

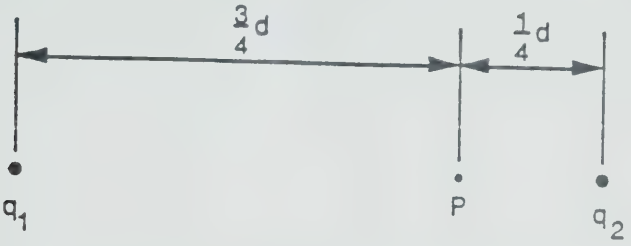
marks) 1. Can an object's speed increase if its acceleration decreases? Explain.

B.1 Sample Solution and Marking Scheme
(3 marks)

Yes. It can be shown using the adjacent v-t graph.The slope of the v-t graph gives the acceleration. In the graph to the right, as time passes, the slope decreases, so the acceleration decreases. Since the graph continues to rise, the speed also continues to increase.



marks) 2. Two point charges, "q_1" and "q_2", of unknown magnitude and sign are separated by a distance "d".

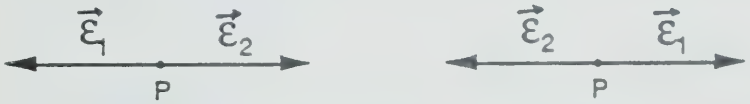


If the electric field is zero at the point P, what can you conclude about the sign and magnitude of the charges?

B.2 Sample Solution and Marking Scheme

(3 marks)

✔ The net electric field at P is the sum of the electric fields of each charge. To have the field
✔ at P be zero, then the sum of the fields due to q_1 and q_2 must be zero. This can only
✔ happen if the fields at P have opposite direction, and so the charges q_1 and q_2 must both
✔ be of the same sign.



✔ The magnitude of q_1 must be greater than the magnitude of q_2 in order to produce a zero
✔ field at P since q_1 is further from P than q_2.

Alternate Solution:

For the fields to cancel exactly, the magnitudes must be equal.

$$|\vec{\mathcal{E}}_1| = |\vec{\mathcal{E}}_2|$$

$$\frac{kq_1}{r_1^2} = \frac{kq_2}{r_2^2}$$

$$\frac{kq_1}{\left(\frac{3d}{4}\right)^2} = \frac{kq_2}{\left(\frac{d}{4}\right)^2}$$

$$\frac{q_1}{9} = \frac{q_2}{1}$$

$$q_1 = 9q_2$$

The magnitude of q_1 must be nine times that of q_2.

marks) 3. De Broglie postulated that matter has a wavelike nature. Use a numerical example to demonstrate why this wavelike character is not observable in our daily experiences.

B.3 Sample Solution and Marking Scheme

(3 marks) ✔ The de Broglie wavelength for a particle can be calculated using

$$\lambda = \frac{h}{mv}$$

✔ As an example, a baseball of mass 150 g moving with a speed of 8.0 m/s would have a wavelength of

✔ $$\lambda = \frac{6.63 \times 10^{-34}\ \text{J}\cdot\text{s}}{(0.150\ \text{kg}) \times 8.0\ \frac{\text{m}}{\text{s}}}$$

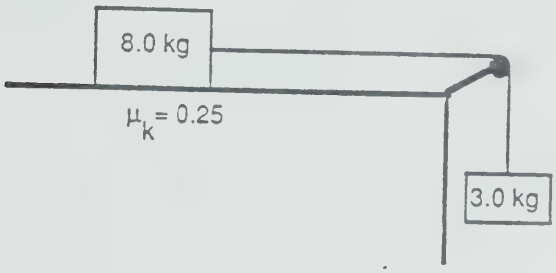
$$\lambda = \frac{6.63 \times 10^{-34}\ \text{kg}\cdot\text{m}^2\cdot\text{s}^{-1}}{(0.150\ \text{kg}) \times 8.0\ \text{m}\cdot\text{s}^{-1}}$$

✔ $$\lambda = 5.5 \times 10^{-34}\ \text{m}$$

✔ This wavelength is much smaller than the size of any available aperture or barrier (nuclear
✔ diameter is about 10^{-15} m) and so cannot be expected to yield diffraction or interference effects.

Part C - Problems - 41 marks (60 min)

1. Two blocks of mass 8.0 kg and 3.0 kg are connected by a light string that passes over a light frictionless pulley. The coefficient of kinetic friction between the 8.0 kg block and the surface is 0.25.



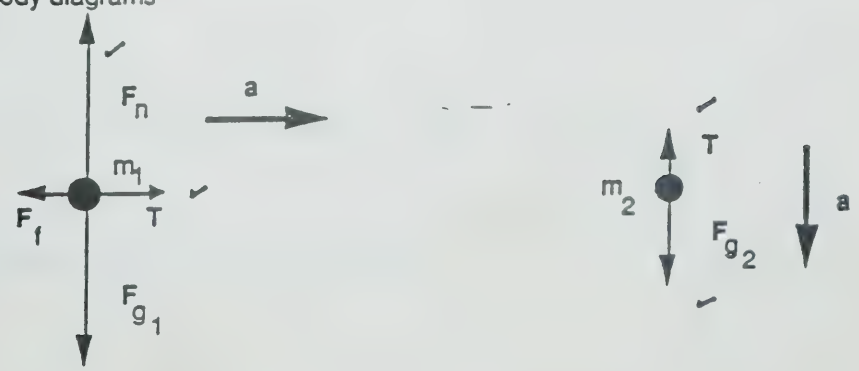
2 marks) (a) Draw a freebody diagram for each block.

7 marks) (b) Calculate the magnitude of the acceleration of each block.

2 marks) (c) Calculate the magnitude of the tension in the string.

Sample Solution and Marking Scheme

(2 marks) a) Free-body diagrams



(7 marks) b) Calculation of the acceleration

✔✔✔✔ Given: $m_1 = 8.0$ kg, $m_2 = 3.0$ kg, $\mu_k = 0.25$. The tensions have the same magnitudes but different directions, and the accelerations have the same magnitudes but different directions. Assume that the 8.0 kg block accelerates to the right, and make that direction **positive**. The positive direction for the 3.0 kg block is downward.

For the 8.0 kg block,

✔ $T - F_f = m_1 a$

✔ Thus $T = m_1 a + F_f$

For the 3.0 kg block,

✔ $F_{g2} - T = m_2 a$

✔ Hence $F_{g2} - (m_1 a + F_f) = m_2 a$

✔ $F_{g2} - F_f = (m_1 + m_2) a$

✔ $m_2 g - \mu_k m_1 g = (m_1 + m_2) a$

✔ $$a = \frac{m_2 g - \mu_k m_1 g}{(m_1 + m_2)}$$

✔ $$a = \frac{\left(3.0 \text{ kg} \times 9.8 \frac{\text{N}}{\text{kg}}\right) - \left(0.25 \times 8.0 \text{ kg} \times 9.8 \frac{\text{N}}{\text{kg}}\right)}{8.0 \text{ kg} + 3.0 \text{ kg}}$$

✔ $$a = 0.89 \frac{\text{m}}{\text{s}^2}$$

✔ The magnitude of the acceleration of each block is 0.89 m/s^2

(2 marks) c) Calculation of the tension

Using the first equation above,

$$T - F_f = m_1 a$$

$$T = m_1 a + F_f$$

✔ $$T = m_1 a + \mu_k m_1 g$$

✔ $$T = 8.0 \text{ kg} \times 0.89 \frac{\text{m}}{\text{s}^2} + 0.25 \times 8.0 \text{ kg} \times 9.8 \frac{\text{N}}{\text{kg}}$$

✔ $$T = 27 \text{ N}$$

✔ The magnitude of the tension in the string is 27 N

2. A truck of mass 3.0×10^3 kg, travelling along a straight, flat road at 9.0×10^1 km/h [N] enters an unbanked curve of radius 1.0×10^2 m that changes the truck's direction to the east while the truck maintains its speed.

5 marks) (a) What are the kinetic energy and momentum of the truck at the moment that it enters the curve?

1 mark) (b) Draw a free body diagram of the forces acting on the truck when it is halfway through the curve.

3 marks) (c) Which of the forces in the free body diagram is the centripetal force and what is its magnitude?

3 marks) (d) What is the coefficient of friction between the truck and the road when the truck is on the verge of sliding?

4 marks) (e) As the truck leaves the curve it collides with a stopped car of mass 1.5×10^3 kg. The truck and car connect together and continue on at 36 km/h [E]. Show by calculation that this is <u>not</u> an elastic collision.

C.2 Sample Solution and Marking Scheme

Given: $m_t = 3.0 \times 10^3$ kg ✔

✔ $$v_t = 90\,\frac{km}{h} = 90\,\frac{km}{h} \times \frac{1000\ m}{1\ km} \times \frac{1\ h}{3600 s} = 25\,\frac{m}{s}$$

$R = 1.0 \times 10^2$ m

$m_c = 1.5 \times 10^3$ kg

✔ $$v'_{ct} = 36\,\frac{km}{h} = 36\,\frac{km}{h} \times \frac{1000\ m}{1\ km} \times \frac{1\ h}{3600 s} = 10\,\frac{m}{s}$$

(5 marks) a) Calculation of Kinetic Energy and Momentum:

✔ $$E_k = \frac{m_t v_t^2}{2}$$

✔ $$E_k = \frac{(3.0 \times 10^3\ kg)(25\ \frac{m}{s})^2}{2}$$

✔ $$E_k = 9.4 \times 10^5\ J$$

and

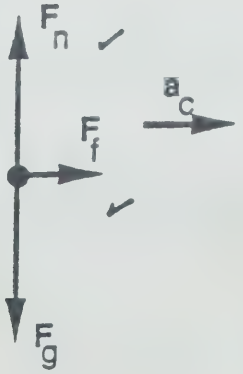
✔ $$\vec{p}_t = m_t \vec{v}_t$$

✔ $$\vec{p}_t = 3.0 \times 10^3\ kg \times 25\,\frac{m}{s}[N]$$

✔ $$\vec{p}_t = 7.5 \times 10^4\ kg \cdot \frac{m}{s}[N]$$

✔ The kinetic energy of the truck is about 9.4 x 10^5 J, while the momentum is
✔ 7.5 x 10^4 kg·m/s [N].

(1 mark) b) Free-body diagram:
From the front of the car:



(3 marks) c) Calculation of centripetal force:

✔ The frictional force (acting horizontally, perpendicular to the truck's direction of motion) provides the centripetal force.

✔ $$F_c = \frac{m_t v_t^2}{R}$$

✔ $$F_c = \frac{3.0 \times 10^3 \text{ kg} \times \left(25 \frac{\text{m}}{\text{s}}\right)^2}{1.0 \times 10^3 \text{ m}}$$

✔ $$F_c = 1.9 \times 10^4 \text{ N}$$

✔ The magnitude of the centripetal force necessary to make the truck follow the curve is 1.9×10^4 N.

(3 marks) d) Calculation of necessary value of coefficient of friction.
Since the truck's wheels are not sliding we use static friction rather than kinetic friction.

✔ $$F_c = F_f,$$

and

✔ $$\mu_s = \frac{F_f}{F_N}$$

✔ $$\mu_s = \frac{F_c}{m_t g}$$

✔ $$\mu_s = \frac{1.88 \times 10^4 \text{ N}}{3.0 \times 10^3 \text{kg} \times 9.8 \frac{\text{N}}{\text{kg}}}$$

✔ $$\mu_s = 0.65$$

✔ The coefficient of friction for the tires on the road is 0.65.

(4 marks) e) Verification that the collision is not elastic.

✔ If the collision is elastic, the total kinetic energies before and after the collision will be the same, within the limits of measurement.

Determine E'_k after the collision:

✔ $$E'_k = \frac{(m_t + m_c)v'^2_a}{2}$$

✔ $$E'_k = \frac{\left(3.0 \times 10^3 \text{kg} + 1.5 \times 10^3 \text{kg}\right)\left(10 \frac{\text{m}}{\text{s}}\right)^2}{2}$$

✔ $$E'_k = 2.2 \times 10^5 \text{ J}$$

✔ Since the kinetic energy of the truck and car is considerably less than the value
✔ determined in Part (a) above, the collision is therefore inelastic.

3. A soccer player kicks a ball with an initial speed of 20 m/s at an angle of 35° to the ground. The goal is 33 m away and the ball just passes under the crossbar as it falls back towards the ground.

marks) (a) How long was the ball in the air before it passed under the crossbar?

marks) (b) How high was the crossbar?

marks) (c) What assumptions did you make in solving this problem?

Problem C.3 Sample Solution and Marking Scheme

Given: $d_x = 33$ m

$v_0 = 20 \frac{m}{s}$, at $\theta = 35°$

(3 marks) a) Find the time the ball was in the air before it passed under the crossbar.

✔ $t = \frac{d_x}{v_{0x}}$

✔ $v_{0x} = v_0 \cos 35°$

✔ $t = \frac{d_x}{v_0 \cos 35°}$

✔ $t = \frac{33 \text{ m}}{20 \frac{m}{s} \times 0.819}$

✔ $t = 2.0$ s

✔ The time before the ball passed under the crossbar was 2.0 s.

(3 marks) b) Calculate the vertical height of the ball as it passes under the crossbar.

✔ Use the time $t = 2.0$ s from the previous part of the problem,

✔ $d_y = v_{0y} t - \frac{gt^2}{2}$

✔ $d_y = v_0 \sin 35° \, t - \frac{gt^2}{2}$

✔ $d_y = 20 \frac{m}{s} \times \sin 35° \times 2.0 \text{ s} - \frac{9.8 \frac{m}{s} \times (2.0 \text{ s})^2}{2}$

✔ $d_y = 3$ m

✔ The height of the crossbar is 3 m.
(Strict application of the rules for significant digits leaves only one significant digit.)

(2 marks) c) Assumptions made in this solution are:

✔ * there are no aerodynamic effects such as drag or lift
* the diameter of the ball can be ignored

✔ Give one mark each for up to two valid assumptions.

4. An alpha particle with a mass of 6.6×10^{-27} kg (atomic number 2 and atomic mass 4) is accelerated from rest through a potential difference of magnitude 3.0×10^{3} V.

marks) (a) How much energy is acquired by the alpha particle?

marks) (b) If the accelerating potential is provided by two parallel plates 18 cm apart, what is the electric field in the region between the parallel plates?

marks) (c) What is the maximum speed of the alpha particle?

marks) (d) What is the magnitude of the electric force exerted on the alpha particle by a carbon nucleus with a mass of 2.0×10^{-26} kg (atomic number 6 and atomic mass 12) when they are 25 nm apart?

Sample Solution and Marking Scheme:

Given: $m_\alpha = 6.6 \times 10^{-27}$ kg,
$q_\alpha = +2$ elem.chg
$m_C = 2.0 \times 10^{-26}$ kg,
✔ $q_C = +6$ elem.chg
$d = 18$ cm
$r = 25$ nm
$\Delta V = -3.0 \times 10^{3}$ V

(2 marks) a) Calculate the energy acquired by the α-particle.

✔ $\Delta E_k = -q_\alpha \Delta V$ (Technically, the kinetic energy gained is the loss of electrical potential energy. Marks should probably not be deducted for failing to follow sign conventions strictly here.)

✔ $\Delta E_k = -2e \times (-3.0 \times 10^{3}\ \text{V})$

$\Delta E_k = -2 \times (1.6 \times 10^{-19}\text{C}) \times (-3.0 \times 10^{3}\ \text{V})$

✔ $\Delta E_k = 9.6 \times 10^{-16}$ J

✔ The α-particle gains 9.6×10^{-16} J of kinetic energy.

(2 marks) b) Calculate the magnitude of the electric field in the region between the plates

✔ $\mathcal{E} = \frac{V}{d}$

✔ $\mathcal{E} = \frac{3.0 \times 10^3\ V}{0.018\ m}$

✔ $\mathcal{E} = 1.7 \times 10^5\ \frac{V}{m}$

✔ The field has a magnitude of 1.7×10^5 V/m (or N/C).

(3 marks) c) Calculate the maximum speed of the α-particle, if it starts from rest:

✔ $E_k = 0$ and $\Delta E_k = E'_k - E_k$, so

$E'_k = \Delta E_k$ and

✔ $E'_k = \frac{mv'^2}{2}$

✔ $v' = \sqrt{\frac{2E'_k}{m}}$

✔ $v' = \sqrt{\frac{2 \times 9.6 \times 10^{-16} J}{6.6 \times 10^{-27} kg}}$

✔ $v' = 5.4 \times 10^5\ \frac{m}{s}$

✔ The speed acquired by the α-particle is 5.4×10^5 m/s

(2 marks) d) Calculate the electric force exerted on the α-particle

✔ $F_e = \frac{kq_\alpha q_c}{r^2}$

✔ $F_e = \frac{2.31 \times 10^{-28} \frac{N \cdot m^2}{elem.chg^2} \times (2\ elem.chg) \times (6\ elem.chg)}{(25 \times 10^{-9}\ m)^2}$

✔ $F_e = 4.4 \times 10^{-12}\ N$

✔ The magnitude of the force on the particle is 4.4×10^{-12} N

Part D - Laboratory Problem - 13 marks (20 min)

1. The wavelength of waves in water can be directly measured. The wavelength of light is not directly measurable.

mark) (a) What do we mean when we say that the wavelength of light is not directly measurable?

marks) (b) Outline an experiment that could be used to determine the wavelength of the light emitted by a helium-neon laser.

marks) (c) Describe the pattern that would be observed.

marks) (d) What quantity would be measured directly in order to calculate the wavelength of the light? Describe a procedure for measuring this quantity that would help increase the precision of the measurement.

marks) (e) State the equation you would use to calculate the wavelength. Indicate clearly the meaning of the symbols in your equation.

marks) (f) Assuming that the laser light has a wavelength in the range 600-700 nm, state approximate values for the dimensions of the experimental apparatus that would produce an easily measured pattern.

Solution and Marking Scheme

(13 marks) a) Because we cannot observe the crests and troughs of the light wave directly, we cannot measure its wavelength directly.

b) The laser light is directed through two narrow parallel slits towards a screen placed some distance behind them.

c) A pattern of equally spaced bright and dark fringes would be produced by the interference of the light passing through the two slits. This pattern is symmetrical about its centre line.

d) The separation of the nodal lines, Δx would be measured. To increase the precision of measurement, the distance across a number of bright fringes could be measured, and Δx determined by dividing this measurement by the number of intervals measured.

e) The equation is

$$\frac{\Delta x}{L} = \frac{\lambda}{d}$$

where Δx is the fringe spacing, L is the distance from the slits to the screen, λ is the wavelength of the light, and d is the slit spacing.

f) If Δx is to be in the range of a few millimetres, with λ about 600 nm, slit spacing of 0.3 mm and an L of about 1 m would work.

Part E - Extended response - 12 marks (20 min)

1. Read the information on solar cells provided below. Describe some of the possible implications of solar cell technology. Your answer should include an identification of some of the difficulties in applying this technology and its possible effects on the way people live. For full marks you should show your knowledge of physics and write your answer in clear concise statements.

   Style: 2 marks; Physics: 2 marks; Technological and Societal considerations: 8 marks.

   The large-scale production of electrical energy using solar cells

   There are two basic types of solar cells, thin-film silicon solar cells and concentrator solar cells.

   Thin-film (amorphous silicon solar cells) presently generate about 60 W/m^2, and operate with an efficiency of about 6%. This type of solar cell is commonly used in electronic calculators. A team of research engineers has recently developed a thin-film solar cell which generates 150 W/m^2, and has an efficiency of 15.5%. By the mid-1990's the generation of electrical energy by thin-film amorphous solar cells is expected to be economically competitive with electrical power plants burning fossil fuels.

   In concentrator solar cells the sunlight is first concentrated to high intensities using lenses or mirrors and then directed onto the surface of the solar cell. Recently a team of research engineers has developed a solar cell with a concentrator that converted 31% of the concentrated sunlight into electrical energy. The light intensity used was between 400 and 700 times the normal intensity of sunlight. The maximum theoretical efficiency of these cells is about 40%. Because concentrator solar cells are expensive to produce, it is expected that thin-film solar cells will be used for the large-scale production of electrical energy.

Sample Solution and Marking Scheme

Marking Scheme

The approximate time for students to answer the question is 20 min. An open ended question of this type will result in a wide range of student answers. The marking scheme which follows includes examples of some of the ideas which students may address.

The marks should be divided as shown:

Style: 2 marks; Physics: 2 marks; Technological and Societal Considerations: 8 marks

1) Style: The response to this question should be written in paragraph form using complete sentences. Ideas should be developed sequentially and logically. Language should be clear and unambiguous. Standard practices in spelling, punctuation and grammar should be observed.

   At the same time, it should be noted that students are writing under pressure of time, and a "first-draft" rather than "final-draft" standard should be expected.

2) Physics: Some of the areas that may be explored include:
   - a discussion of the transformation of the energy of light to the energy of electricity;
   - the use of the photon concept to explain the photoelectric effect;
   - a discussion of the relationship of the angle of sunlight to the energy available to the solar cell;
   - an estimation of the size of a solar cell to run a household appliance;
   - a discussion of the various types of optics that may be used in a concentrated solar cell.

3) Technological and Societal Considerations: Some of the considerations which students may include in their answers are listed below.

Technological Considerations:

- the large surface areas required for mounting the solar cell arrays
- the optimum orientation of the solar cell array during the day, and as path of sun changes throughout the year
- energy output of solar cells on cloudy and/or rainy days
- development of less-expensive, low-maintenance types of "concentrator" solar cells to reduce space requirements for solar cell array
- the storage of extra energy (batteries or production of hydrogen gas) to provide a source of electrical energy at night, or when light intensity is too low
- contamination problems related to dirt and environmental pollution
- removing snow and ice from the surface of the solar cell array in winter
- integrating electrical energy produced by solar cells with that supplied by the public utilities
- the dependence of economic competitiveness on solar intensity which varies with latitudes
- maintenance in remote areas.

Societal Considerations:

- decreased pollution by reduced use of fossil fuels
- health considerations related to reduced pollution
- conservation of valuable non-renewable sources of energy (coal, oil, natural gas, nuclear fuel)
- possibility of use of excess energy to operate various forms of transportation (cars, motorcycles, etc.)
- may provide convenient, inexpensive sources of energy for remote areas, and for energy-poor nations
- safety problems related to distribution of electrical energy from solar cell array to point-of-use, and possible production, storage and use of hydrogen gas produced by electrolysis of water
- aesthetic problems related to size and placement of solar cell arrays
- control of solar cell development by multi-national corporations.

OAIP Physics Part III (Pages 4 to 6) APPENDIX B

Scoring Created Response Instruments

The scoring of created response instruments involves a number of subjective judgments on the part of the scorer. These subjective judgments are minimized and the scoring is more reliable if a detailed scoring scheme is followed. A scoring scheme has been provided for each created response instrument in the OAIP: Physics.

The scoring policy adopted for OAIP: Physics is that of 'a point for a point'. One scoring point is awarded for each clearly identifiable step or element which makes an essential contribution to a correct and complete answer. An element is scored either '✓' or 0; that is, an element is either there or it isn't and is credited or not credited accordingly.

The details of the scoring policy adopted for created response instruments is summarized below. A '✓' indicates that a scoring point is awarded for the element indicated. The teacher should use discretion in the use of the scoring policy.

Scoring Policy Adopted for Created Response Instruments

Setting up the Problem

✓ extraction of relevant data (including units and assignment of data to the correct variable)
✓ statement of convention (e.g. take downward as positive)
✓ listing of implied or assumed values (e.g. $v_i = 0$, $a = g$)
✓ statement of relevant general principles or laws
✓ drawing of a sketch showing the situation and the objects (e.g. projectile thrown from building)

Equations

✓ choice of relevant equation (e.g. $F = ma$)
✓ correct substitution of data into the equation

Mathematical Computation

✓ re-arranging the variables in an equation to isolate the unknown (either before or after substitution)
✓ performing key steps needed to obtain the final answer such as obtaining the value of a constant from tables or a calculator, simplification, factoring, or applying a mathematical identity

Final Answer

✓ magnitude (numeral and exponent)
✓ unit
✓ direction (when applicable)
✓ sign (when appropriate) (e.g. gain or loss of energy)
✓ number of significant figures (when appropriate)
✓ final statement (answer to the question)

Special Considerations

(i) Free Body Diagrams

✓ each correctly labelled vector

(ii) Vector Sketches

for each correct vector

✓ label (e.g. v(a/g))
✓ magnitude where appropriate (e.g. 400 m/s)
✓ direction where appropriate (e.g. [N])
✓ orientation with reference to other vectors (e.g. head to tail, tail to tail, etc.)

(iii) Vector Scale Diagrams

✓ indication of scale
✓ appropriateness of scale
✓ constructed length of each given vector
✓ constructed direction of each given vector
✓ length of each measured vector
✓ determination of the true length of each measured vector
✓ direction of each measured vector /(using scale)

(iv) Sketched Graphs

✓ correct shape
✓ correct placement with reference to origin
✓ correct slope at key locations (e.g. origin)

(v) Plotted Graphs

✓✓ appropriateness of title
✓✓ assignment of variables to axes
✓✓ labelling quantities on axes
✓✓ labelling units on axes
✓✓✓✓ appropriateness of axes scales
✓✓✓✓ accuracy of plotted points
✓✓ appropriateness of indication of plotted points (error bars)
✓✓✓✓ appropriateness of line of best fit
✓✓✓ neatness

NOTE: 1. See the Scoring Scheme for Graphs on page 39.
2. Allocate the tick '✓' marks indicated, sum, and divide by 5 to achieve a realistic weighting.

(vi) Ray Diagrams

✓ each appropriate ray
✓ each correct arrowhead
✓ each appropriate angle
✓ each characteristic of the image

Guidelines for Implementing the Scoring Policy

1. Students should be encouraged to substitute units with numerals into equations and to carry units throughout the solution of a problem. Physical quantities, such as mass, force, and momentum, are completely described only when units are included with numerals. The substitution of units has several merits: it provides a check on the accuracy of the equation; it points out the need for consistent units; and it identifies the unit of the answer. Students should not be penalized if units are dropped part way through the solution of a problem. Some units are cumbersome to carry. But if units are dropped, students should write 'units dropped' as a signal to the scorer of a conscious decision to do so.

2. Mathematical computations should not take precedence over the physics in a question. Accordingly, a minimum of points has been allotted for arithmetical manipulation. For this reason the use of calculators in created response instruments is optional.

3. A mechanical error should result only in the loss of marks for the step in which the error occurred. The examiner should trace the solution through to the final answer without deducting further marks unless additional errors are made.

4. Students should be encouraged to show their complete solution to a problem. However full marks are assigned to the correct answer even if intermediate steps are omitted provided the logic is sound.

5. The final answer to all created response instruments should be in the form of a statement. This statement is an answer to the question asked in the problem.

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